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BASE MAP ANALYSIS OF COASTAL CHANGES USING AERIAL PHOTOGRAPHY. (U)

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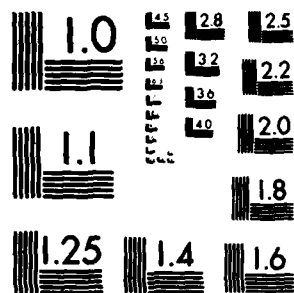
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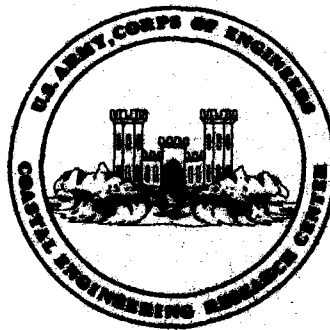
Base Map Analysis of Coastal Changes

Using Aerial Photography

by
Craig H. Everts and Deborah C. Wilson

TECHNICAL PAPER NO. 81-4

NOVEMBER 1981



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PREFACE

This report describes a technique to quantify changes in shoreline position using time-sequence aerial photos. Aerial photos, which are usually available more often than repetitive ground surveys, may be the only source of past shoreline change data. The technique was developed during a sediment budget study conducted for the U.S. Army Engineer District, Philadelphia.

The report was prepared by Dr. Craig H. Everts and Deborah C. Wilson, under the general supervision of N.E. Parker, Chief, Engineering Development Division. Dr. C. Galvin, W.A. Birkemeier, and D.E. Lichy reviewed earlier drafts of the manuscript.

Comments on this publication are invited.

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TED E. BISHOP
Colonel, Corps of Engineers
Commander and Director



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CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.852	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.01745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins ¹

¹To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: $C = (5/9) (F - 32)$.

To obtain Kelvin (K) readings, use formula: $K = (5/9) (F - 32) + 273.15$.

BASE MAP ANALYSIS OF COASTAL CHANGES
USING AERIAL PHOTOGRAPHY

by
Craig H. Everts and Deborah C. Wilson

I. INTRODUCTION

Time-sequence aerial photography is frequently used in determining past shoreline positions. Often, this photography is the only source of such information. Most methods of determining shoreline position changes from aerial photography require that measurements be taken directly from the photos. Stafford (1971), for example, presents an excellent description of such a method used in beach erosion surveys. The method requires that the absolute distance scale be established for each photo (or in some cases, each set of photos), a time-consuming and often difficult task.

This report presents a technique in which such problems are minimized. A master base map containing the exact location and outlines of various subaerial reference points is constructed using the earliest and latest sets of aerial photos available. Separate base maps for each in-between photo set are then duplicated from the master. The image of the aerial photos is superimposed at the map scale, and features of interest are traced on each base map. Distances along specified lines drawn normal to shore on each map are then measured to shoreline features. When a comparison between each base map is made, these distances provide shoreline change data through time.

II. BASE MAP ANALYSIS TECHNIQUE

Application of the base map analysis technique requires three main tasks: (a) the construction of the base maps, using a transfer instrument to superimpose the image of fixed features on the aerial photography to the maps; (b) the superposition and recording of the desired shoreline and other features from the aerial photography to the base maps; and (c) the reduction of data to determine the required measurements.

1. Construction of the Base Maps.

a. Procedure. An accurate master base map, which is critical to the success of the analysis, is constructed in four steps. The first step is to select a suitable map scale, slightly larger than the scale of the largest scale aerial photo set, to ensure that all photo sets are traceable on the base map. Mosaics of the earliest (in time) and the latest sets of the largest scale aerial photos are prepared, and the master base map is drawn on a sheet of high-quality, dimensionally stable paper cut at the appropriate length and width to include the largest scale mosaic.

The second step is to determine reference points, which are features common to all photo sets, to establish the absolute location of the images of the aerial photos on the base map. Reference points must be included on all photo sets, and must be nonchanging through time; e.g., if a road corner is selected, the road must not have been widened during the earliest to latest interval of the photo sets. Cultural features such as road junctions make excellent reference points. The reference points must be point definable, flat lying, if

possible, and all at about the same elevation. A tower or smokestack is inappropriate because when it is not in the center of the photo it will appear tilted (relief displacement error), making the exact location at ground level difficult to determine. Finally, reference points should be chosen close to the shore and in sufficient numbers so that at least three are present for each aerial photo analyzed. The reference points are then drawn on the master base map.

After the reference points are located on the master base map, a straight line, approximately parallel to the shoreline, is drawn the length of the study area. This line is then used in the third step of locating and numbering transects on the map. A series of lines, or transects, at right angles to the shore-parallel line, are drawn from the line across the shoreline. The spacing interval of the transects depends on the study requirements. For straight coastlines with no structures, an interval of 1 kilometer should be sufficient for most coastal engineering needs (Everts and Czerniak, 1977). When structures are present and near inlets, river mouths, or headlands, a transect spacing of 0.5 kilometer or less is probably warranted. In some cases, such as in a groin field, one or more transects in each compartment may be required. Measurements will be made from the intersection of the transects and the shore-parallel line to the desired coastal feature, e.g., the shoreline, on each base map. Thus, the measurements made along exactly the same line on each map eliminate errors due to nonidentical measurement points.

When the master base map has been completed and checked, the final step of preparing a base map from the master for each in-between photo set is accomplished. Copies are made and then checked for exactness of scale between each copy.

b. Instrument Requirements. An important requirement for the construction of the master base map, as well as for the photo analysis and data reduction, is an instrument which allows the image of small-scale features on aerial photos to be superimposed and viewed on a base map. The instrument should also have the capability to rectify slightly oblique images (tilt) to a vertical equivalent and to magnify or reduce imagery to the scale of the base map.

Scale variations, which are the largest sources of error in aerial photography, occur when the aircraft either fails to hold a constant altitude during a single flight or maintains different altitudes on successive flights. Thus, an error results when a comparison is made between two photos of slightly different scale showing the same location. Tilt errors occur when the optical axis of the camera is tilted from true vertical as the photo is taken, causing a variation in scale. Relief displacement errors occur where the images of objects above the mean surface elevation are projected outward from the center of the photo and the images of those below the mean surface elevation are displaced inward of their true location (Stafford, 1971, p. 29). When maximum elevation differences are less than 6 meters, as they are along much of the U.S. Atlantic coast, relief displacement errors are small. These errors can be further reduced by using only the central part of the photo for measurement purposes (possible when photos show at least 30 to 40 percent overlap, as indicated in Stafford, 1971, p. 29) and by selecting flat- or low-lying objects as reference points.

The Bausch and Lomb Zoom Transfer Scope meets the requirements for application in the base map technique. Use of the scope nearly eliminates scale and

tilt errors, and greatly reduces relief displacement errors by proper reference point selection. The scope is an optical train type viewing instrument which, using the camera lucida principle, provides the superimposition of the image of the photo on a horizontal plane (McGivern, Martin, and Benjamin, 1972). The image of a photo, using a variable magnification system (optical zoom), a one-direction magnification, and an image rotation system, is ratioed, deformed, rotated, and transformed to establish the best fit with the planimetric base map.

2. Aerial Photo Analysis.

This task involves the tracing of the desired beach, nearshore and wave features on the base maps by carefully matching reference points on the photo to those on the maps. Using the transfer instrument to match the variations in scale and tilt, thus eliminating errors, the photo image and the base map reference points appear superimposed. Selected coastal features are then traced from their superimposed images on the base map. For measurement accuracy, a hard lead, sharp pencil is used to trace shoreline features (e.g., solid line for water and shore structures, dashline for wetted bound, dash-dot line for dune line). Colored pencils are used for the other features not requiring as exact a location (e.g., solid red line for submarine bar and shoal position, blue dashline for breaking wave crests, solid blue line for nonbreaking wave crests). Care must be taken to work as much as possible from the centers of each photo when tracing features on the maps. This reduces errors due to tilt, and is the reason a large overlap area between photos is important.

3. Data Reduction.

Measurements of shoreline features (waterline, wetted bound, and dune position) are taken at the intersection of transects with the shore-parallel reference line on the base maps to the feature traced on the map. Any feature on the base map can be measured, using the same procedure. Measurements may be taken using an architect's scale with interpolations to 1/32 or 1/64 inch (0.012 or 0.006 centimeter) for an estimated accuracy of 0.003 to 0.0015 centimeter, which is 2 to 1 meter on a scale of 1:10,000.

III. DATA REQUIREMENTS AND SELECTION OF COASTAL FEATURES

Accuracy in obtaining various data from aerial photos is based on the objective selection of beach and nearshore features with characteristics distinguishing these features from other coastal features.

1. Shoreline Position.

Changes to the shoreline position are determined by identifying shoreline features such as the waterline position, the wetted bound position, and the dune line position. Generally, the wetted bound is the best shoreline position marker to use because it does not vary appreciably over a tidal cycle, and the position is identifiable on most aerial photos. The following criteria should be used to identify the shoreline position:

a. Waterline.

(1) Identification. The line indicating the exposed beach-water intercept. A sharp gray (landward) to black (seaward) tonal change and the presence of white foam often help to define this boundary.

(2) Potential Problems. The boundary position varies with changes in wave conditions and with tidal elevation. For example, the average beach slope in southern New Jersey is 0.03 and tidal range is 1.2 meters; the horizontal position of the waterline will vary 40 meters over a tidal cycle. The correction for tide effect is made using tide data, beach slope, and the time period the photos were obtained.

b. Wetted Bound.

(1) Identification. This is the line forming the boundary between sand saturated at the time of high tide and drier sand landward of that limit (Stafford, 1971). Dry sand is light gray on aerial photos. Dolan, et al. (1980) found that the wetted bound (high waterline) moved an average of only 1 to 2 meters over a tidal cycle.

(2) Potential Problems. The wetted bound position is dependent upon changing wave conditions, tidal elevation, and water table fluctuations which cause variations from an "average" location. Sometimes a debris line obscures this boundary. In a test at Ludlam Beach, New Jersey, the wetted bound was identifiable on 80 percent of aerial photos analyzed (Everts, DeWall, and Czerniak, 1980).

c. Dune Line Position.

(1) Identification. Where the frontal dune is relatively continuous, the seaward edge of vegetation may be used.

(2) Potential Problem. If the coast is retreating, the loss of dunes and vegetation may preclude using the dune line to determine the shoreline retreat rate.

2. Shore Structures.

Shore-normal structures, such as groins and jetties, and shore-parallel structures such as breakwaters, seawalls, revetments, and bulkheads, may be traced on base maps using the different time-sequence sets of aerial photography. This provides an approximation of when the structures were constructed, with the accuracy of the approximation depending on the time interval between the aerial photo sets. Plan view dimensions of the structures may also be measured. Probably the most important use of determining shore structures on the base maps is in evaluating the effectiveness of the structures when the structure position is coupled with shoreline change data.

3. Submarine Bars and Shoal Position.

Underwater bars are sometimes visible beneath the water surface, but most often their position may be located by waves breaking over the bar. The breaking waves in aerial photos appear as light areas of definite shape (long continuous lines) in the dark gray water. Submarine bars are usually elongated features, with their long axis paralleling the coast. An analysis of the time-sequence photo sets will determine the location, orientation, and distance from the waterline of these bars.

4. Wave Approach Angle.

Wave crests before and at breaking, when traced on the base maps, provide the plan view geometry of the waves and the effects of structures and natural features on the wave patterns. Although waves are discernible on most photos, underexposed photos may cause some difficulties. Breaking waves are easily recognized as lines of white water and foam in the normal dark gray water. Unbroken wave crests appear as lighter line tones.

Wave approach angle data are not sufficient to determine the longshore transport rate. A large number of aerial photo sets are required for the extraction of net wave approach direction data. However, an aerial photo analysis can, in some cases, provide the location of longshore transport nodal points (reaches), using the following procedures: (a) by plotting the direction of wave approach (left or right of shore-normal) relative to shore at closely spaced alongshore intervals (transects) on each base map, (b) by calculating for each transect, using all the base maps, the number of time sets when waves approach from left or right of shore-normal, and (c) by plotting a ratio of left-to-right approaching waves on a master base map to determine whether the preferred approach direction changes along the shore. The approach direction on many barrier islands changes near inlets, indicating a possibility that the net direction of longshore sediment transport also changes.

5. Overwash Deposits.

The base map procedure allows the tracing of any planform feature in an exact scale from an aerial photo to a map. One example is overwash deposits which are of particular interest in coastal engineering because these deposits often represent large volumes of sand removed from the beach. An overwash deposit is the material moved inland from the beach and deposited in a delta-like form during storm events. The boundaries of the deposit are usually easy to identify on aerial photos, and when the aerial extent of the overwash deposit is planimetered, the volume of the deposit may be estimated by obtaining ground measurement of the deposit thickness.

IV. EVALUATION OF TECHNIQUE

The value of any aerial photo analysis depends on the accuracy and reliability of the procedure used; therefore, it is necessary to know the types and magnitudes of errors that have been incorporated in the results. Two categories of error exist. One is the error inherent in selecting features in aerial photos such that changes in the position of the features allow something else to be quantified. An example is the use of changes in the wetted bound position to

establish a shoreline change rate. The second category of error is that inherent in the technique used, e.g., tracing and measuring errors in the base maps.

Ground survey data and aerial photography for Ludlam Beach, New Jersey, analyzed by Everts, DeWall, and Czerniak (1980), provided a means to evaluate the effectiveness of the use of the waterline and wetted bound obtained from aerial photos to establish shoreline change rates as measured on the ground. In addition, their photo analysis evaluated the procedures used in the base map technique, and the results are as follows:

(1) Over a long study period, the waterline and wetted bound equally reflect average beach changes as determined by the MSL shoreline survey results, where the field survey technique is the most accurate.

(2) The wetted bound showed less longshore variability in position than the waterline (variability being measured by the mean standard deviation). The difference between the amount of variability shown by the wetted bound and survey MSL shoreline was not statistically significant.

(3) No significant error due to reproduction using a Xerox 1860 Printer was found in an evaluation of the base maps. The mean difference was 0.34 percent (i.e., 0.34 centimeter in 100 centimeters on the map). Therefore, beach features from the aerial photo sets were traced on nearly identical base maps, and measurements were made at nearly the same points on each base map.

(4) A possible cause of error in an analysis of beach features on aerial photos is the inability to consistently select the position of the feature at the exact location. The least selection difficulty occurred in establishing the waterline position. The most difficult to select was the location of the longshore bar. The mean error in selecting the position of the beach features was 0.01 centimeter (absolute). No real difference was found in the measurements made in "complicated" areas and those made in "simple" areas (sharp, shore-parallel, straight-line features).

(5) Measurement error, i.e., repeatability errors in measuring distances on the base maps, varied from 0 to 0.0015 centimeter (absolute). The average error was 0.00023 centimeter.

V. DISCUSSION

The base map technique allows a visual comparison of features along the entire study shoreline, i.e., beyond the bounds of the individual photos, as well as a means to quantitatively measure changes in the features through time. This freedom also allows lesser known relationships to be studied. For example, bars and breaking waves show a natural alongshore continuity and, by analyzing the base maps, it is possible to measure how the position of such features change as a function of time and location. The base map analysis of the crest orientation of incoming waves will provide information about wave refraction, a task which might be difficult to do by analyzing the photos directly.

Scale changes are accounted for by relating everything to the common scale of the base map, reducing the inherent error involved in measuring distances on two photos. Because important features are transferred to a base map, measurements of features such as shoreline position can be made where required along shore-normal lines, spaced as dictated by study needs and not by the reference points on the aerial photos. This flexibility is useful in calculating shoreline changes for an entire barrier island.

Although the base map analysis technique involves steps not required in the direct photo-measurement method, the technique may be worth the extra effort in certain applications, e.g., sediment budget studies, projects that require information on possible regions of longshore transport reversal, studies that require the time-sequence construction and the plan view dimensions of coastal structures, and possible requirements for information on the location and persistence of longshore bars and inlet shoals.

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